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Title: PROBLEM OF WIND-INDUCED LEVEL VARIATIONS AND SEICHES IN THE
BALTIC SEA USSR

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PROBLEM OF WIND-INDUCED LEVEL
VARIATIONS AND SEICHES IN BALTIC SEA

[figures at the end]

V. M. Skornyakov

As is known, in some regions of the Baltic Sea, particularly in the Neva Bay, considerable though short-lived variations in sea level are observed, in some instances attaining the order of 150-200 centimeters. These variations coincide with temporary intensification of the winds, up to storm proportions. Therefore, these variations are explained by the wind-induced driving-on and driving-off of the water level. However, a more thorough study of tide recordings shows that, simultaneously with the appearance of the wind-induced variations there also take place free variations of the sea level, so-called seiches which, in turn, induce periodic level variations, sometimes approaching extreme amplitudes of the order of 30-60 centimeters. It is seen that the amplitude of the latter variations is not great enough to enable us to consider the seiches accountable for greater level variations, occasionally causing floods in Leningrad. Evidently there takes place some other phenomenon connected with seiches since, according to data obtained by V. P. Dubov [1], who did research on seiches, the periodic occurrence of the latter is in fair agreement with the times of water level rise and fall during floods.

The study of seiches in the Baltic Sea, by comparing tide recordings at different locations, yielded some very interesting results. It was determined that these seiches develop along two basic directions, namely: (1) Southern Baltic - Gulf of Finland, and (2) Southern Baltic - Gulf of Bothnia. In some rare instances seiches form in the direction of the Gulf of Bothnia - Shkhernee Sea and the Gulf of Finland. In each of these directions seiches have their own period of variation.

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Computation of this period according to Dubois' method gives 27 hours for the first direction, 36 hours for the second direction, and about 29 hours for the third direction. As a rule, in all of the analysed cases there was observed a single node seiche with antinodes at the end points of the above mentioned directions, with the base line passing in the middle of the sea, approximately along the line, Irben Strait - Cape Landsort.

The Seiche-induced variations in sea level, are, however, of complex nature, determined by the superimposition of seiches which develop in various directions. In view of the different periods of the latter, level variations are characterized by variable period and amplitude, where the amplitude varies within very wide limits, approaching maximum when the seiches are in phase. In the latter instance, this coincidence of the seiche phases leads to resonance, in which case there takes place sharp variations of the Neva Bay level leading to Leningrad floods.

From the many examples available to this author, a description of one of the most characteristic follows. For this purpose there were taken simultaneous recordings of level variations at three extreme sea locations: (1) at Toppila, northern part of the Gulf of Bothnia, (2) at Ystad, southern Sweden and (3) at Koivisto, eastern part of the Gulf of Finland. As is seen from Figure 1, at all three locations level variations are of periodic nature, determined by the development of seiches in the above-mentioned directions. In view of the different periods of the seiches, the phase of sea level variations is constantly being displaced and, when the periods of seiches coincide, which in this case took place in the period of time between 30 January and 6 February, there took place a sharp increase in amplitude of level variation approaching 140-160 centimeters. Further phase displacement

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leads first to a sharp and then gradual decrease in amplitude variation of level. However, if the energy of variation is still great, or an additional impulse was imparted to the vibrating system, then after some time, the amplitude of variation will again increase and will reach a maximum at the next phase coincidence.

c o n t i n e n t s	1. Toppila
	2. Ystad
	3. Kolviisto
January February	

Figure 1. Variations of level at Toppila, Ystad and Kolviisto from 20 January 1932 to 6 February 1933. [For figure 1, see appendix.]

This periodic amplitude change of level variation, so called "pulsation," which is characteristic of a fixed vibrating system, is observed frequently in the Baltic Sea, especially during the autumn season, when it receives additional impulses from the frequent storms. This example was intended to illustrate the order of magnitude of level variations due to seiches and resonance phenomenon. What is the order of magnitude of these variations due to wind-induced water swells and ebbs?

The statistical method of processing observed data, which are used in ordinary practice, yields only the averaged observations, which as indicated by the computations of L. P. Rudovits [2] do not exceed ± 25 centimeters for swells and -16 centimeters for ebbs. This method does not give us the limiting values of this phenomenon, since in such

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a case a different approach must be used in the treatment of the observed data.

For this purpose the author employed a graphical method by drawing a smooth curve to average out the seiche-caused periodic variations in level. This curve seems to show the average level position, about which these variations take place, and therefore affords the possibility of their elimination. The difference between the maximum and minimum of the given curve gives the amplitude of the wind-induced water swell. An example of such determination of the amplitude of water swell for Kronstadt is given in Figure 2, which shows at the same time the seiche-like nature of variation of level and the resonance phenomenon, which caused a rise in level of 106 centimeters above the base, with the amplitude of vibration of approximately 160 centimeters. It can be seen that the wind-induced water swell accounts for 60 centimeters.

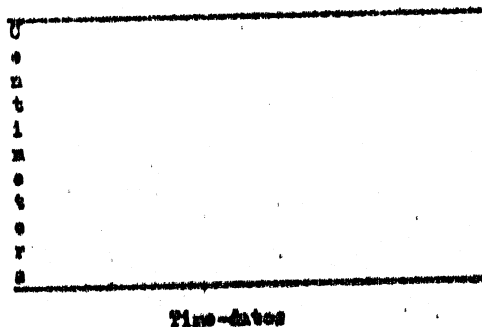


Figure 2. Variations of Level in January 1947. [see the appendix]

In conclusion we note the effect of resonance upon the maximum levels at different sea locations, and the possibility of origination in the deep sea layers of seiche-induced periodic currents. Many years of observations of the variation in the level of the Baltic

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Sea, indicate that the difference between the extreme levels at the shores of the Central Baltic is in the order of 1.8-2.2 meters, and in the direction of the farthest sea locations this goes up to 4-4.2 meters. This increase in the difference between the extreme levels at the farthest sea locations cannot be explained by the wind-induced well-ebb phenomena, but only by the seiche-induced level variations, as well as by the resonance effect, the example of which has been cited above, since both of these processes are accompanied by variations in level, the amplitude of which increases as we go from the central sea locations toward the farthest points. In reference to the periodic currents, that are supposedly caused by seiches, we can note that their presence was confirmed by observations made on the experimental ship "Aranda" in 1930.

Automatic recorders from this ship installed in the region south of the island of Gotland registered a current which varied continuously with time over a period of 3 days and had a period of 17 hours and a variable velocity between 4 to 26 centimeters per second. The presence of periodic currents in the Baltic was also pointed out also by K. N. Zubov [3]. However, he considered them as of inertial type. This consideration cannot but be doubted, since the currents in this case were observed at comparatively great depths, which could not be caused by the wind circulation, and even if this were possible, these currents would quickly decay as a result of loss of kinetic energy.

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2. L. P. Rudovits, "On the Variation of Level in Baltic Sea," GOI (1917)
3. M. N. Zubov, Dynamical Oceanology (1942)
4. N. A. Bagrov, "Ebbes and Swells in a Closed Shallow Sea," Doklady GOIN, No. 18 (1947)

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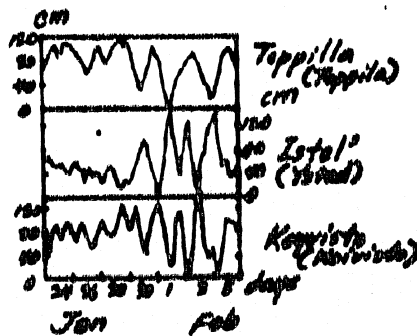


Figure 1. Oscillations in the levels at Tappilla, Istel', and Koyvisto from 20 Jan 1942 to 5 Feb 1942.

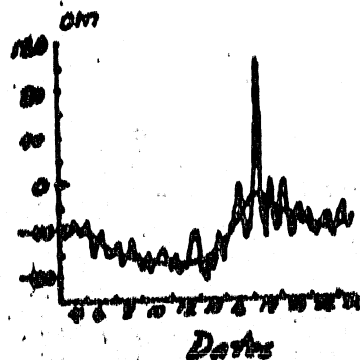


Figure 2. Oscillations in the level in Jan 1947.

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